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DEVELOPMENT OF A NEUTRON SPECTROMETER TO ASSESS BIOLOGICAL RADIATION DAMAGE BEHIND SPACECRAFT MATERIALS

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Astronauts who spend months and years traveling long distances in spacecraft and working on other planets will be subjected to high energy radiation of galactic and solar origin without the protection of the Earth's thick (one writer has called it buff) atmosphere and magnetic field. The lack of natural protection will allow high energy cosmic ray particles and solar protons to crash directly into relatively thin spacecraft walls and planetary atmospheres producing energetic secondary particles in these collisions.

A substantial fraction of these secondaries will be neutrons that carry no electric charge and, consequently, are difficult to detect. At sea level on Earth the remaining neutrons are the result of many generations (approximately 10) of collisions, have very low energies (scientists call them thermal neutrons), and do not penetrate deeply into the human body. They do contribute to the natural background radiation seen by humans on Earth, but much of the dose is only at the surface or skin of the body.

In the International Space Station or on the surface of Mars, the secondary neutrons will be the result of only one or two generations of interaction due to the thinner (about a factor of 20 compared to the Earth's atmosphere) walls or atmosphere, have considerably more energy and penetrate deeply into the human body. In addition, neutrons are substantially moderated by hydrogenous material such as water. A significant fraction of the water exists in the astronaut's body. Therefore, the neutron can not only penetrate more deeply into the body, but also be stopped there and deposit all or most of its radiation dose in organs such as the liver, spleen, kidney, etc. We hypothesize that the risk of serious cancers will be increased for the exposed humans.

The portable, real time neutron spectrometer being developed by our team will monitor the environment inside spacecraft structures and on planetary surfaces. Activities supported by this grant will evaluate the neutron environment inside several candidate spacecraft materials at accelerator facilities. These experiments will enable engineers to choose the structure materials that minimize the production of secondary neutrons. With the information that the neutron energy spectrometer produces, scientists and doctors will be able to assess the increased risk of cancer and develop countermeasures. The instrument itself will include an alarm system to warn astronauts when high radiation fluxes are occurring so that they can seek shelter immediately.

The neutron spectrometer being developed at the Johns Hopkins Applied Physics Laboratory and School of Medicine has also been selected to fly on the Mars 2005 Lander. An engineering prototype spectrometer has been tested and calibrated with mono-energetic neutron beams at Columbia University. Detection efficiencies of 5% or more have been demonstrated in the 1-20 MeV neutron energy range. This prototype unit is flying at high altitudes in fighter aircraft out of NASA Dryden to verify its operating capability and obtain some atmospheric neutron data similar to the spectra to be experienced in the International Space Station or on the surface of Mars.

Our research program for this grant will have four components:

- 1) construction of an improved engineering model instrument dedicated to accelerator facility testing of spacecraft materials,
- 2) experimental characterization of the engineering model with respect to its neutron detection efficiency and ability to discriminate against charged particles including calibration of the instrument,
- 3) flight qualification of the engineering model,
- 4) measurement of neutron spectra produced by energetic proton and heavy ion beams colliding with candidate spacecraft structure and shield materials.

We will use the Loma Linda University Medical Center for proton beam testing and the Lawrence Berkeley Laboratory or Brookhaven National Laboratory for heavy ion beams to produce the collisions with the materials.

The instrument will consist of two sections. The front end section will contain the detector head and front end electronics as seen in Figure 1. Figure 2 shows the remaining instrument which consists of analog and digital pulse processing electronics. The primary purpose of the instrument is to yield the neutron spectrum produced behind shielding material due to nuclear reactions between the incident particle beam and the shielding material. This task is accomplished by recording neutron energy deposition events in a Lithium Drifted Silicon surface barrier detector (SiLi) and using a modeling approach to back out the most probable incident neutron spectrum.

The detector head will be placed behind the shielding material in an optimal position to record neutrons energy deposition events in the SiLi detector. The anti-coincidence shield allows us to discriminate charged particles events from neutron events in the SiLi detector. As an artifact of this measurement scheme it may be possible to do charged particle identification in the anti-coincidence shield which will be a scintillator. This is not a goal of the project but may be possible with a simple modification.

The remaining instrument (Figure 2) will process the analog pulses and prepare them for storage in a Multi-Channel Analyzer (MCA) which converts the analog pulse heights to digital values. A gate signal from the anti-coincidence channel will disable the first MCA when a charge particle is detected in the scintillator anti-coincidence shield. A second MCA can record the charged particle energy deposition events in the SiLi detector. The use of a second MCA to record charged particle events was not a original goal but is a simple addition that will be added in the second year of the project.

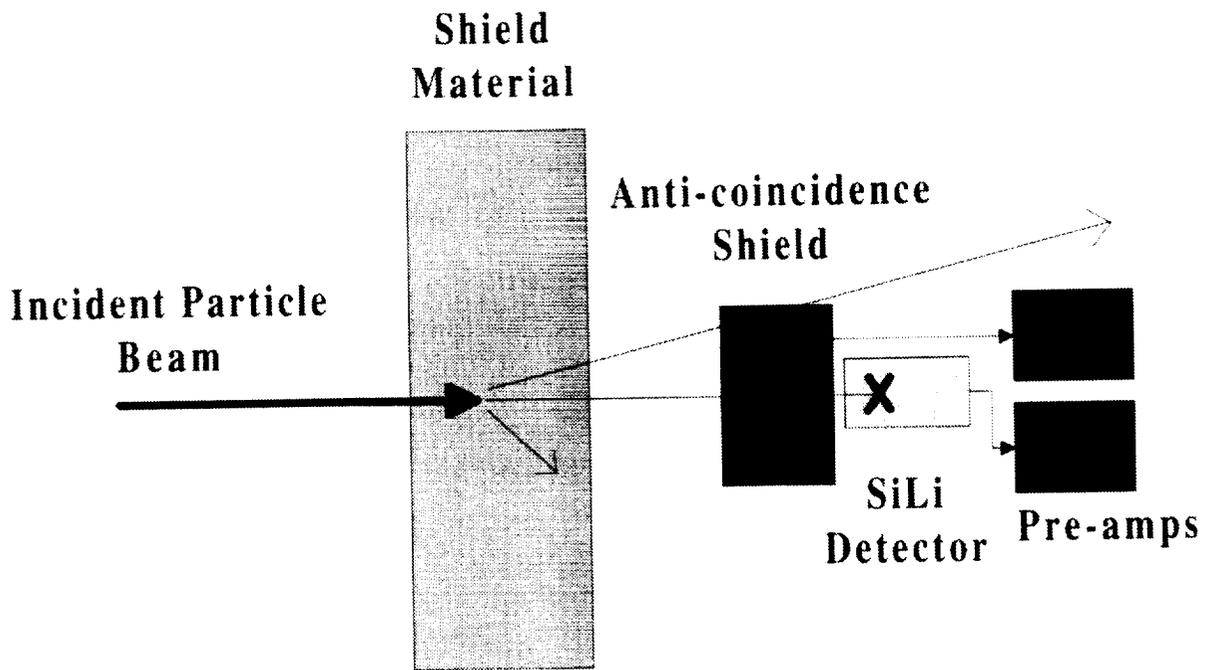


Figure 1. Detector head showing the major elements. The incident particle beam shown has a nuclear interaction in the shielding material resulting in three secondary particles. The top particle just clips the anti-coincidence shield, the middle particle (assumed a neutron) deposits energy in the SiLi detector, and the bottom recoil is absorbed in the shield material. The SiLi event is processed in the bottom pre-amp and sent to the remaining instrument for processing.

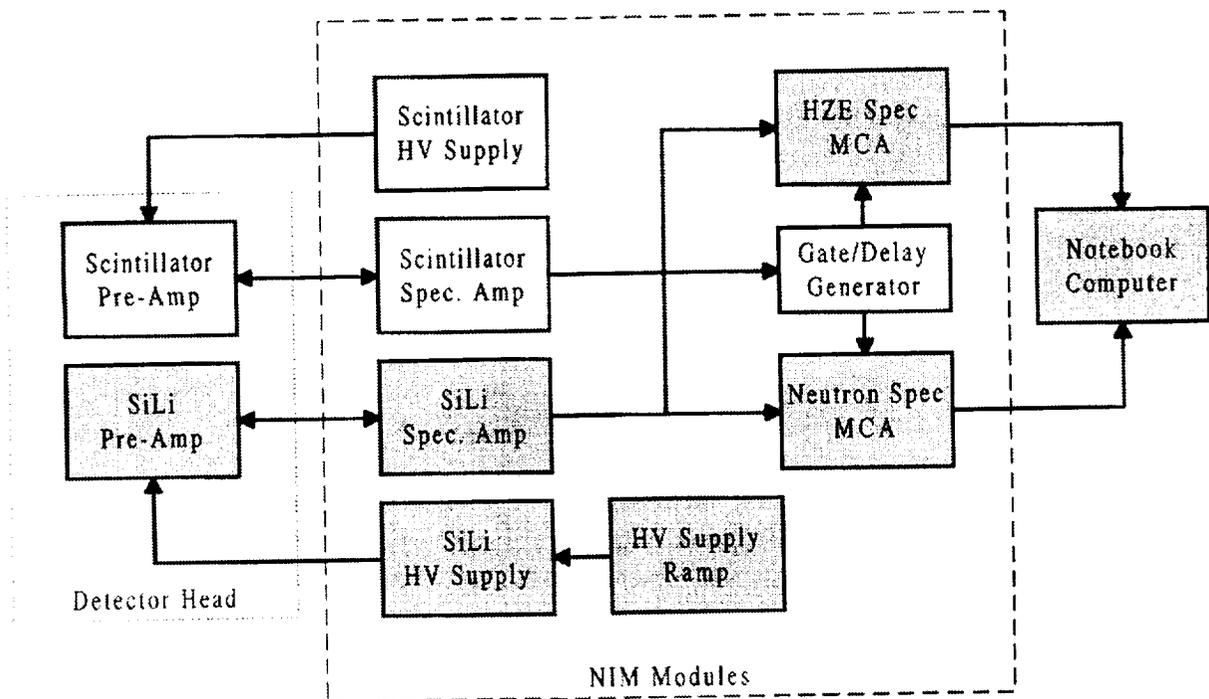


Figure 2. A block diagram of the major electronic subsystems are shown in this figure. The detector head sits in the primary beam path (detectors not shown). The NIM modules are 8 to 10 feet out of the primary beam path but still in the beam cave. The notebook computer and operator are located outside the beam cave and linked to the equipment via serial ports. The darker shaded areas indicated the SiLi detector channel while the lighter shaded areas indicate the anti-coincidence channel.